

REPRINTED FROM THE

Journal of the Society of Chemical Industry,

DECEMBER 31, 1887.

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MANCHESTER:

CAMMOTT & CO., PRINTERS, NEW BRIDGE STREET, STRANGEWAYS.

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THE WELDON-PECHINEY PROCESS FOR THE MANUFACTURE OF CHLORINE FROM CHLORIDE OF MAGNESIUM.

BY PROFESSOR JAMES DEWAR, M.A., F.R.S.

It will be in the memory of my hearers that the late Mr. Walter Weldon, just before the sad event which deprived industrial chemistry of his services, had been actively engaged in attempting to develop a second chlorine process. It is a fact—and a fact of which I have no doubt Mr. Weldon was fully conscious—that it is a most rare thing for one man to make two great successes as a patentee dealing with the same subject. Yet he was always hopeful of the success of this new process, which was patented on the 23rd June, 1884, under the title of "Improvements in obtaining, partly in the free state and partly as vapour of hydrochloric acid, the chlorine of the chloride of magnesium of aqueous solutions of chloride of magnesium, or of mixed solutions of chloride of magnesium and chloride of sodium." It would take too much time and space to go into the history of previous attempts to economise chloride of magnesium. Suffice it to say that though numbers of patents have been taken (including several by Mr. Weldon himself at about the time of the industrial application of his great process for the regeneration of manganese) for the direct utilisation of magnesium chloride in the production of chlorine, none have been successful. Before proceeding to a description of the process I should say that, besides the patent already mentioned, there are others, taken at the same time and subsequently, partly based on suggestions of Mr. Weldon's, but chiefly the inventions of M. Pechiney—namely, patents for the various pieces of apparatus, diagrams of which are shown. I think my hearers will agree with me that the chemical side of this question has not been so difficult to deal with as the mechanical side, and that the development of the process has required the application of engineering talent of the very highest order. In fact the credit for the realisation of this process must be divided between three names—those of Mr. Weldon, M. Pechiney, and the able chief of Pechiney's staff, M. Boulouvard. Mr. Weldon himself pointed this out in the letter which accompanied his account of the process for this Society's report on the Chemical Exhibits at the Inventions Exhibition (see note, p. 526, September, 1885). The process has been worked at Salindres for about five months, on an experimental plant designed for the production of one ton of chlorine per day, and may be briefly described as follows, the description being in great measure in M. Pechiney's own words:—The raw material employed is hydrochloric acid. The process consists of the following operations:

- (1) Dissolving magnesia in HCl.
- (2) Preparation of oxychloride of magnesium.
- (3) Crushing, breaking, and sifting the oxychloride.
- (4) Drying the oxychloride.
- (5) Decomposing the oxychloride.

FIRST OPERATION.—DISSOLVING THE MAGNESIA IN HCl.

The magnesia to be dissolved in HCl is a portion of that which results from the fifth operation. The HCl itself also results in part from the fifth operation, and the remainder from the decomposition of salt. The operation in question is somewhat difficult, owing to the considerable rise in the temperature which it produces. It has to be performed slowly to prevent the solution from boiling, which is apt to occur with violence. To this end the operation is performed in an ordinary well, similar to those used in the Weldon manganese process. The agitator is put in motion; the hydrochloric acid is run in slowly, and magnesia is then added little by little as fast as it will dissolve. When the temperature of the solution reaches the point of ebullition the operation is stopped for a short time, to allow the solution to cool. [One means of moderating the elevation of the temperature consists in employing, for the saturation of the acid, not magnesia only, but a certain quantity of oxychloride *in powder*, resulting from the sifting which forms part of the third operation. This portion of the oxychloride cannot be treated in the decomposing furnace, because it would render the charge too compact, and therefore difficult to be traversed by gases. On the other hand, it will be well understood that the solution in HCl of magnesia, combined with $MgCl_2$, will disengage less heat than the solution of magnesia alone, the destruction of the oxychloride itself absorbing a considerable amount of heat.]

When the well contains a sufficient quantity of the solution, the operation is terminated by adding to the liquid (which always retains a little acid) some further small quantities of magnesia, in order to precipitate part at least of the foreign oxides (oxides of iron, alumina, etc.), and thus prevent the accumulation of these impurities. There is also added a certain quantity of solution of $CaCl_2$ for the purpose of transforming into $MgCl_2$ and So_4Ca a part at least of the magnesium sulphate resulting from the presence of sulphuric acid in the hydrochloric acid employed. The solution is then pumped into standing vessels, wherein the insoluble matters (oxides

and calcium sulphate) are deposited, and the clarified liquor is then ready for the following operation.

SECOND OPERATION.—PREPARATION OF THE OXYCHLORIDE OF MAGNESIUM.

The solution resulting from the first operation is evaporated in boilers down to the point at which it will contain not more than about 6 equivalents of water, and is now ready for conversion into oxychloride.

The apparatus in which this conversion of the chloride into oxychloride is performed is illustrated by Figs. 1 and 2 of the accompanying diagrams, Fig. 1 being a vertical section, and Fig. 2 a horizontal section. It consists of an annular sheet iron vessel A resting on rollers *a, a*. The bevelled wheel *b* acting on the pinion *c* gives a continuous but slow rotary motion to the vessel A. M is a fixed frame upon which are mounted three agitators G, D, E, as well as the shafts *d* and *f*. These agitators are rotated from the shaft *f* by means of a bevelled wheel gearing with a bevelled wheel on the shaft of the central agitator D, which also carries a spur wheel gearing with two equal spur wheels on the shafts G and E. The fast and loose pulleys B and B', driven by a band, give motion to the whole machine.

The quantity of MgO used at Salindres in this operation is about $1\frac{1}{2}$ equivalents per equivalent of $MgCl_2$.

This magnesia is brought to the above described annular vessel by means of a chain of buckets which elevates the magnesia and then lets it descend through a strainer under which the horizontal rotary motion of the annular vessel brings successively every portion of the $MgCl_2$ which the latter contains. The operation lasts only about twenty minutes. The whole mass becomes very hard and during solidification disengages much heat. It is then in the form of solid pieces, of different sizes. This operation finished, the material is discharged from the annular vessel into little waggons, which, by means of a lift, bring it to an upper floor, where the reaction, which was not quite finished, continues for some time.

The composition of the oxychloride in this state is approximately as follows:—

Impurities..	4.00	
Water	41.16	
$MgCl_2$	35.00	Cl = 26.16 per cent.
MgO	19.84	= 1.346 equivalents per equivalent of $MgCl_2$.

100.00

THIRD OPERATION. — BREAKING, CRUSHING AND SIFTING OF THE OXYCHLORIDE OF MAGNESIUM.

The oxychloride produced by the preceding operation is in the form of pieces of various sizes along with a small quantity of powder. It is necessary to reduce this material to morsels, of which the largest shall not be larger than a walnut, and further to clear these pieces of all dust, which might, when in the decomposing furnace, prevent the free passage of air through the mass.

To this end the oxychloride, after remaining for some time in the boxes mentioned in the preceding operation, is crushed in a special apparatus consisting of cylinders bristling with diamond points. In passing between these cylinders the material is broken to pieces of the required size. It then falls into a rotary sieve, which separates from it all that can pass through a metallic cloth of which the threads are 5 millimetres apart. That which passes through this sieve constitutes the powder of oxychloride spoken of above. This dust can be either dissolved in HCl with magnesia in the first operation, or be

reintroduced into the operation of preparing the oxychloride. We have succeeded in reducing the proportion of dust to 20 per cent. of the total weight of oxychloride.

FOURTH OPERATION.—DRYING THE OXYCHLORIDE OF MAGNESIUM.

The operation of drying previous to decomposition is necessary, because in the decomposition of the oxychloride by heat and air a larger quantity of free chlorine and a smaller quantity of hydrochloric acid result: 1st. If the material to be decomposed contains less water; and 2nd. If the decomposition is performed at a higher temperature. The previous drying is necessary for the realisation of the first condition. It is indirectly necessary for the realisation of the second condition, because the less water the material contains the less will it lower the temperature of the decomposing furnace.

Whereas chloride of magnesium containing six equivalents of water cannot be dried even partially without a large quantity of HCl being disengaged, the oxychloride can be made to lose a considerable quantity of water without the escape of more than a small portion of HCl. However, the desiccation must not be carried on at a temperature above 250° to 300° C. The only practicable means of drying the oxychloride therefore is to submit it to the action of a current of hot gases. The necessity of avoiding the formation of dust during the operation made it impossible to use the mechanical agitator for exposing the surfaces of the pieces of oxychloride to the current of hot gases. We have therefore adopted a system of working which consists in making a train of wagonettes with shelves one above the other, on which the oxychloride is spread in layers of 5 to 6 centimetres thickness, circulate in a flue in a direction opposite to that traversed by the hot gases.

The apparatus in and by which the drying of the oxychloride is effected is shown in Figs. 3 and 4 of the accompanying diagrams. Fig. 3 is a cross section of the flue or tunnel of brickwork through which the trucks filled with oxychloride pass. Fig. 4 is a longitudinal section of the said flue and trucks. The flue is furnished at its ends with the locks A, B, which permit trucks to enter and leave without opening direct communication between the interior of the flue and the atmosphere. To introduce a truck, the door *a* is opened, and is shut again after the truck has been put in the lock. The dampers *c* and *d* are then lifted, and by means of the pusher rack G the truck is made to advance into the flue. Having crossed the space separating it from truck No. 10, it pushes this truck and the whole train forward, itself occupying the place of No. 10, and No. 1 being pushed partly into the exit lock B. No. 1 is now drawn into the lock B by the hook D worked from outside. The damper *d* is then shut, the door *b* opened and the truck withdrawn by hand. The hot gases enter the tunnel by the pipe M, and leave it by the pipe N. They may be produced in any manner, but it is important that their temperature should not exceed 300° C. Filling the trucks is a somewhat difficult operation, for it is necessary that the oxychloride should be spread in regular layers on each of the seven shelves of the trucks. We have succeeded in filling rapidly by means of the apparatus shown in Fig. 5. This apparatus consists of three parts:—1. A measurer A formed of seven equal spaces corresponding to the seven shelves of the truck. The bottom of each of these spaces is shut by an inclined door *a*, furnished with a lever. The seven levers are jointed to a connecting rod B, which is worked by a screw, two bevelled wheels and a hand

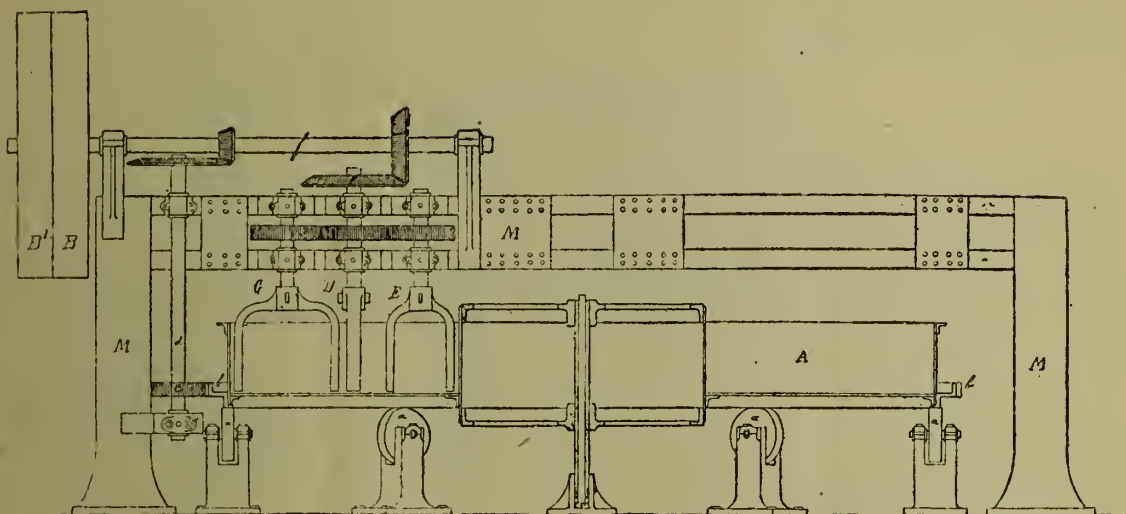


FIG. 1.

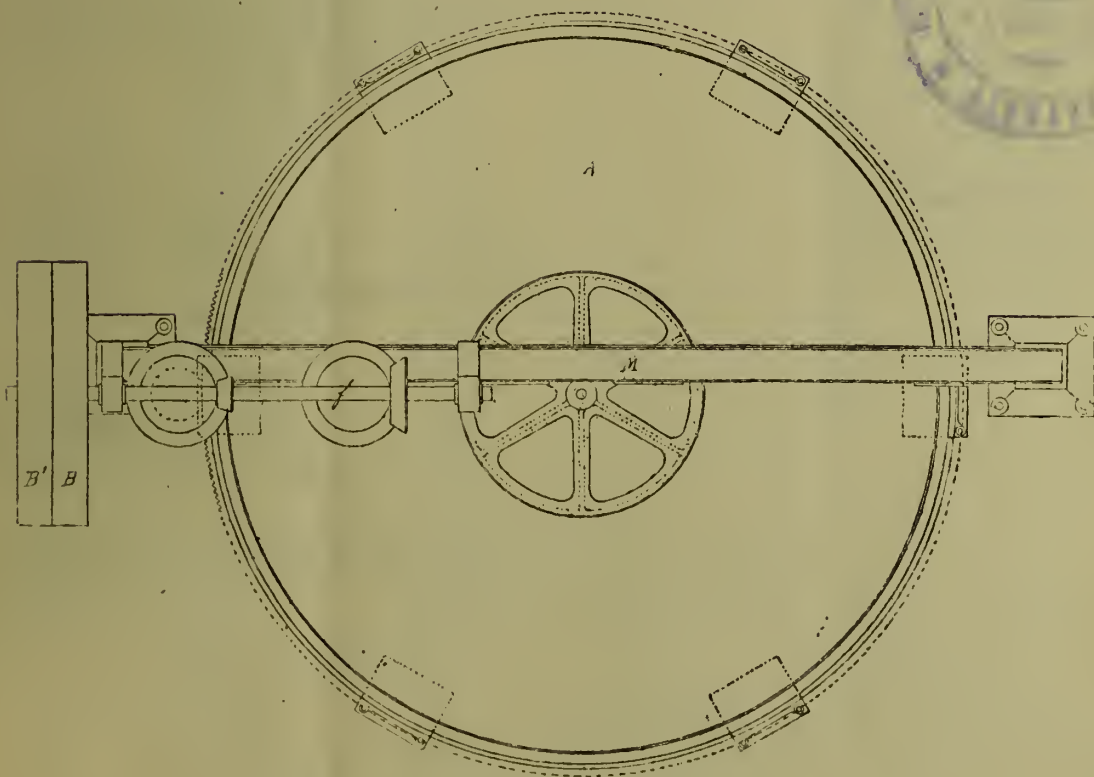


FIG. 2.

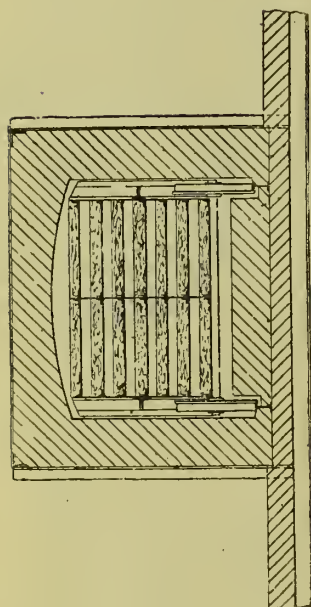


FIG. 3.

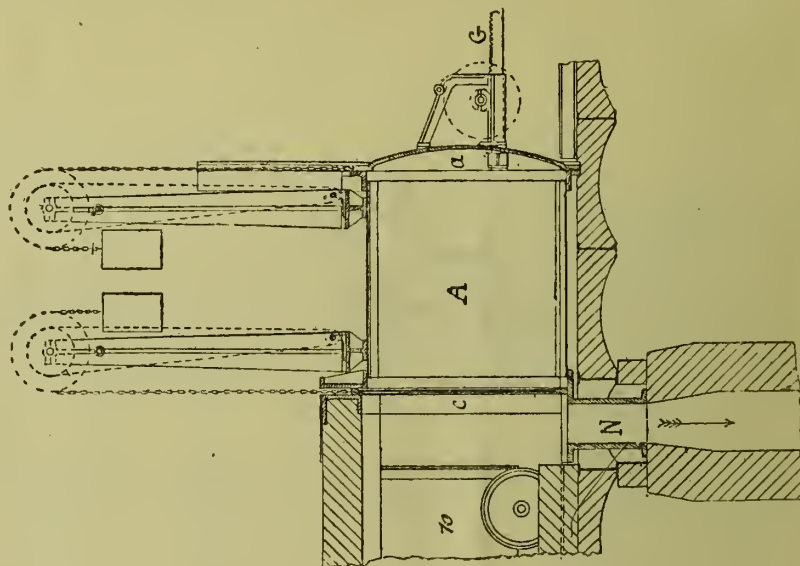


FIG. 4.

wheel C, so that all the seven doors are shut or opened simultaneously. 2. Below the measurer is a sort of hopper D, also divided into seven compartments and mounted on wheels. 3. Under these two parts, and on a level with the drying apparatus, is a reversible frame E, on which the truck to be loaded is placed. In the drawing, this frame and a truck is represented as overturned—i.e., in the position in which it should be to be loaded. Before being put in this position, the truck is furnished with a series of sheet-iron diaphragms, *d*, to limit on each side the thickness of the oxychloride. Two of the diaphragms are placed on each shelf, being introduced endwise by making them slide in like drawers. At the bottom end of the reversible frame are two rails R, on which the truck rests. These rails are supported by levers *f* and *g*, by which the truck can be raised so as to bring it against the top end of the reversible frame. The levers *f* and *g* are worked by the larger lever G, which is itself worked by the screw H and the crank M. The diaphragms are fixed by screws *n*, whose heads press against the cross-bars *o*, which form part of the diaphragms. The reversing movement is effected by the toothed wheel, pinion and crank shown by the dotted lines. When the diaphragms have been placed as described, the frame is reversed and the hopper D brought over the truck. The measurer having been filled with oxychloride, the wheel C is turned, opening the doors *a* and letting the material drop, which, being guided by the hopper D, descends into the spaces between the shelves and the diaphragms. The reversible frame is then brought to its normal position, the diaphragms are removed, and the truck is ready to enter the drying apparatus. The following table will indicate the results of this process of desiccation:—

TABLE A.

RESULTS OF DRYING OXYCHLORIDE OF MAGNESIUM.

Equivalents of MgO per Equivalent of Cl in the Oxychloride.		Percentage of Cl in the Oxychloride.		Percentage of H ₂ O in the Oxychloride.		Cl Lost per Cent. of the Cl in the Wet Oxychloride.	H ₂ O Lost per Cent. of Water in the Wet Oxychloride.
Wet.	Dry.	Wet.	Dry.	Wet.	Dry.		
1.333	1.359	25.73	32.89	44.27	30.89	1.12	11
1.394	1.511	25.91	32.05	41.97	29.81	1.67	19
1.313	1.531	25.80	32.73	45.93	27.97	7.13	55
1.316	1.511	26.16	33.30	45.16	27.09	6.60	57

During this operation the oxychloride loses 60 to 65 per cent. of its water; at the same time it disengages in the state of HCl from 5 to 8 per cent. of its chlorine. The dried product is therefore richer in magnesia than the original material. Thus 100 of original oxychloride, of which the analysis is given above under "Preparation of Oxychloride of Magnesium," is reduced by drying to 73.36, formed of:—

Impurities...	4.00
Water	15.86
MgCl ₂	32.69 (Cl=21.43)
MgO	20.81
	73.36

and of which the centesimal composition is:—

Impurities..	5.47
Water	21.62
MgCl ₂	41.45 (Cl=33.30 per cent.)
MgO	28.36 = 1.511 equivalents per 1 equivalent of MgCl ₂ .
	100.00

As 100 parts of oxychloride before drying contained of Cl 26.16, and have been reduced to 73.36 parts containing Cl 24.43, the drying has caused a loss of Cl 1.73. Say that 6.6 per cent. of the Cl put in work have been lost in this operation. This loss will rarely, if ever, exceed 8 per cent. We shall have occasion to speak of it further on.

FIFTH OPERATION.—DECOMPOSITION OF OXYCHLORIDE OF MAGNESIUM.

The first idea which occurs to one's mind for carrying out this operation is to employ an apparatus analogous to a retort, heated externally, into which the dried oxychloride should be charged and air passed through. But this method of working is impracticable for several reasons, the chief one being that both magnesia and oxychloride of magnesium are very bad conductors of heat. Supposing a retort of practical size and dimension filled with oxychloride of magnesium, it would require a considerable time and an enormous quantity of fuel to bring the centre of the mass to a red heat. And not only would there be a great expenditure of fuel, but the operation would be executed under extremely bad conditions from the point of view of getting free Cl. Experience has proved that the proportion of free Cl driven off is always greater and the proportion of HCl always smaller the more rapidly the oxychloride is brought to the maximum temperature. For these reasons, and for others (for instance, the porosity of refractory retorts), the apparatus shown in Figs. 6, 7 and 8 was adopted instead of the retort. This apparatus and the method of working it may be briefly described as follows:—

Fig. 6 shows a vertical section, alike of the furnace proper and of the movable regenerative burner. Fig. 7 shows a horizontal section, alike of the furnace proper and of the said movable regenerative burner. The upper part of this section is taken along the line C, D, Fig. 6, and the lower part of it along the line E, F, Fig. 6. Alike in Fig. 6 and in Fig. 7, the movable regenerative burner is shown in the position, in relation to the furnace proper, which it occupies during the operation of heating up the working chambers of the latter. Fig. 8 shows a vertical section of the furnace proper, taken at right angles to the section shown in Fig. 6. A, A, A, A, Fig. 8, are four narrow decomposing chambers, having very thick walls. The upper extremity of each chamber A opens into the combustion chamber, B. The lower extremity of each chamber A communicates with one of the four horizontal channels, *a, a, a, a*. D, Fig. 6, is the movable regenerative burner. It consists of a system of cast-iron pipes, contained in an envelope of masonry, which envelope of masonry is encased with iron plates, and securely armatured. The cast-iron pipes are of rectangular section, and each of them is divided, by two vertical partitions, into three compartments, *i, o, u*. The central compartments, *o, o, o*, etc., convey gaseous fuel into the combustion chamber B, and the side compartments *i* and *u*, convey air into the combustion chamber. The gaseous fuel is supplied by the main pipe upon which is the valve N, Fig. 7, from which main pipe it passes by the pipes V and C, Fig. 7, into the flue C, Fig. 6, from which flue C it enters the compartments *o, o, o*, by apertures at the bottom of those compartments. Having reached the upper extremity of the compartments *o, o, o*, the gaseous fuel issues into the combustion chamber B, by the small pipes *d, d, d*, Figs. 6 and 7. The air which is to burn the gaseous fuel enters at the bottom of the compartments *i* and *u*, and, having risen to the upper extremity of those compartments, issues into the combustion chamber by the wide flat pipe T, Fig. 6. It will be seen from Fig. 6 that the

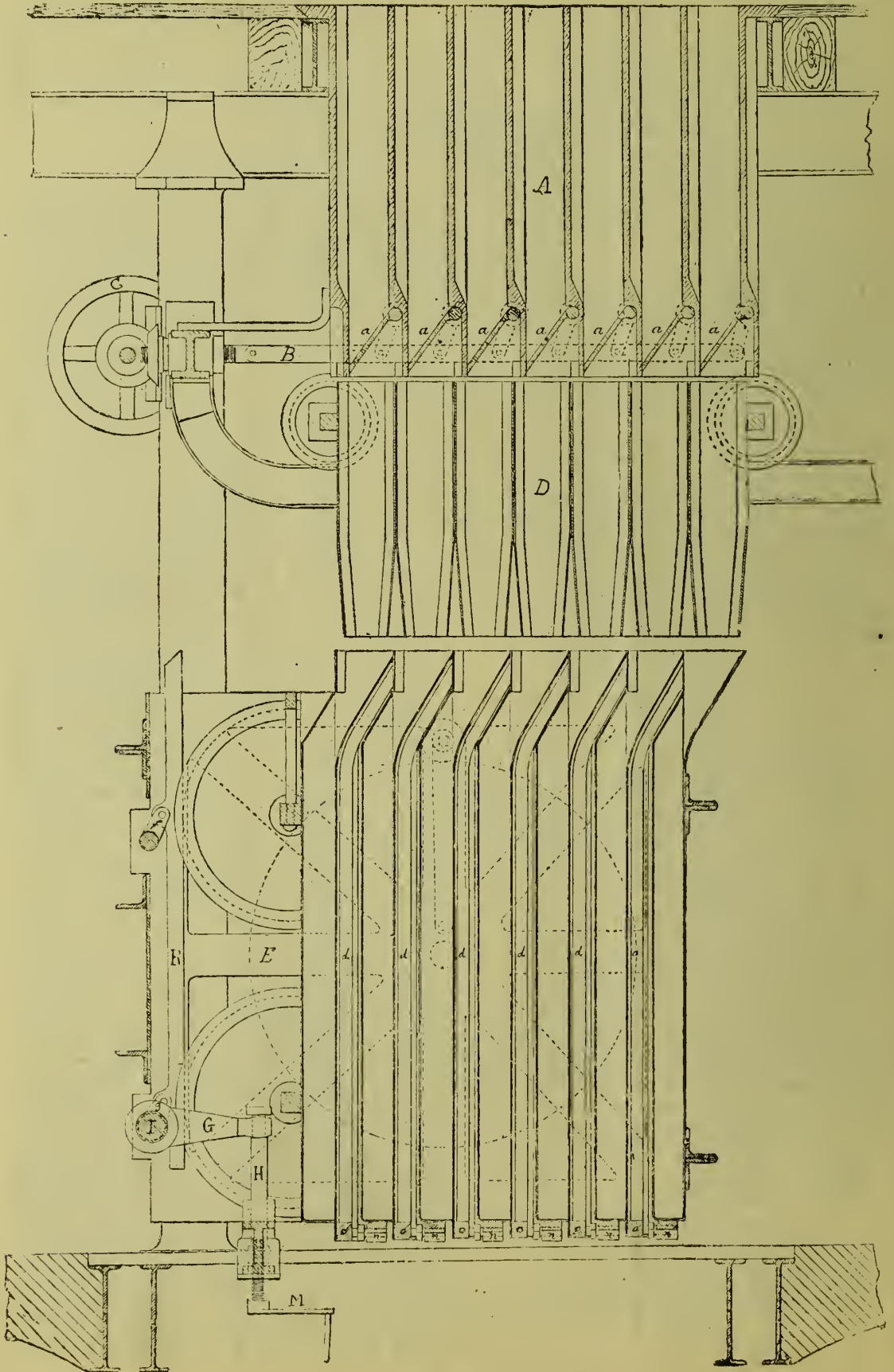


FIG. 5.

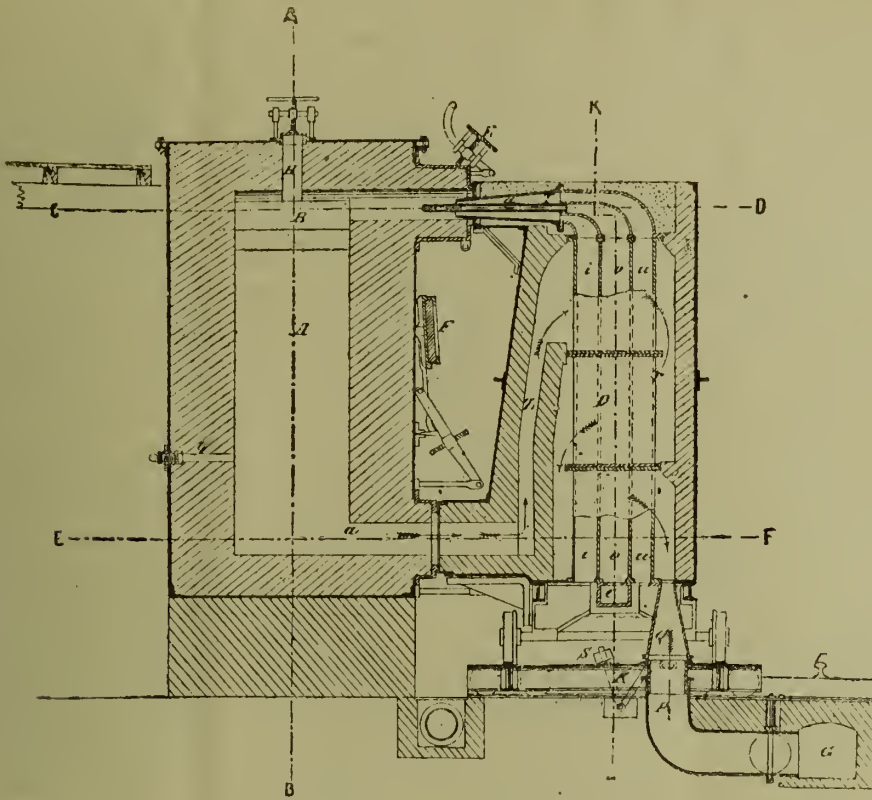


FIG. 6.

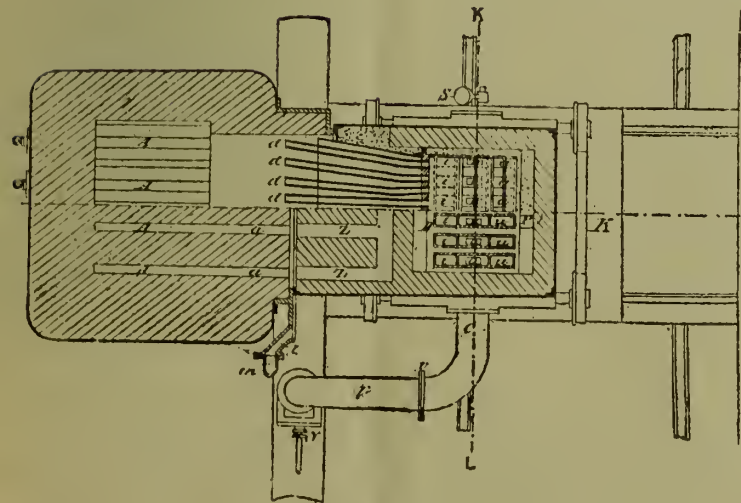


FIG. 7.

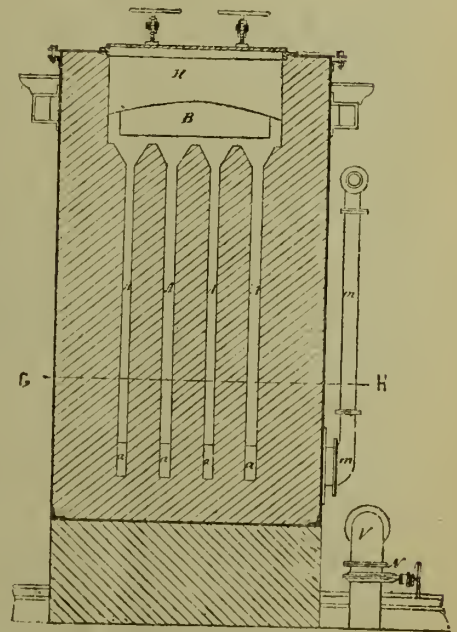
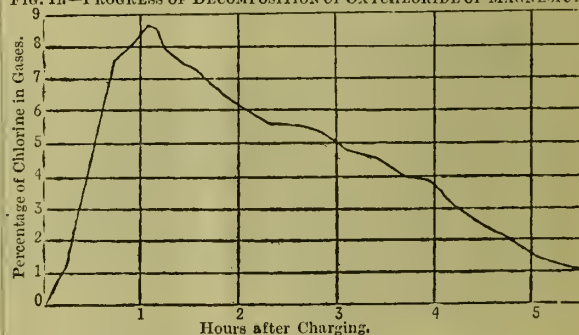


FIG. 8.

small pipes d, d, d , pass through this wide flat pipe T, and that the small pipes d, d, d , are a little longer than the flat pipe T. The pipe V, Fig. 7, is fixed to the main pipe on which is the valve N. The pipe C, Fig. 7, is fixed to the movable regenerative burner. When the movable regenerative burner is in the position, in relation to the furnace proper, in which it is shown in Figs. 6 and 7, the pipe C communicates with the pipe V, at the point U, Fig. 6. The joint at U is one which can be readily made and readily unmade. From the combustion chamber B, products of combustion enter the narrow working chambers, A, A, A, A, by the upper extremity of each of them. After traversing these chambers downwards, they pass off, by the four horizontal channels a, a, a, a , into the movable regenerative burner. Following the direction of the arrows in Fig. 1, they pass upwards through the flues Z, Z, Z, Figs. 6 and 7, and then travel downwards, circulating round the rectangular cast-iron vertical pipes which have been described, and passing between those rectangular pipes, and then passing off from the burner by the pipe P, Figs. 6 and 7, which conveys them to the flue G, Fig. 6. In thus passing downwards through the movable burner, they heat the gaseous fuel which is passing upwards through the compartments o and the air which is passing upwards through the compartments i and u . They are then conveyed to the apparatus employed for the drying of the oxychloride. The pipe P, which is fixed, communicates with the flue by which products of combustion pass off from the movable burner by the piece Q, the lower part of which fits into the upper part of the pipe P, in such manner that the piece Q can be raised or lowered by the lever S. It will be seen from Fig. 6 that the whole regenerative burner is mounted on wheels. When the burner is in the position in relation to the furnace proper, in which it is shown in Figs. 6 and 7, the wheels of the movable regenerative burner stand on rails upon a truck K, K, Figs. 6 and 7. This truck also stands on rails. When the truck is drawn a short distance from the furnace proper the rails on the truck K become in such a position in relation to other rails, one of which is shown at r , Fig. 6, that the burner can be transferred to other rails, and drawn along them on to another truck installed opposite another furnace. Thus, while oxychloride of magnesium is being heated in a current of air in one furnace, the movable regenerator can be employed to heat up the decomposing chambers of another similar furnace. The working of the apparatus will now be easily understood. When the four working chambers A, A, A, A, have been heated to a sufficient temperature, the first step is to close the valve N, Fig. 7, and so to cut off the supply of combustible gas to the movable regenerative burner. The pipe C, Figs. 6 and 7, must then be disconnected from the pipe V, Fig. 7, the pipe P must be lowered, and then the truck on which the whole regenerative burner is supported must be drawn away from the furnace proper, until the wheels of the burner are opposite the rails, one of which is marked r in Fig. 6. The openings by which products of combustion have entered the working chambers must now be closed by the door E, Fig. 6, and the opening by which those products of combustion have passed off from the working chambers must be closed by the door F, Fig. 6. One door E and one door F suffice for the whole furnace. The doors E and F are hung on hinges; and when they are in position to close the openings to which they correspond, they are pressed tightly against their seats by screws. The decomposing chambers A, A, A, A, are charged with oxychloride of magnesium, in small pieces, from a tip-waggon charged therewith which has been pre-

viously brought into position on the top of the furnace. The oxychloride enters the decomposing chambers by the opening H, Figs. 6 and 8. The cover or door which closes this opening is seen in Figs. 6 and 8, but is not marked with any letter. This cover having been removed, a hopper is brought over the opening H, and oxychloride is then poured into the hopper, whence it falls into the chambers A, A, A, A. The door or cover of the opening H is then rapidly replaced and air is admitted into A, A, A, A, through apertures in the door E. The oxychloride rapidly becomes heated by absorption of some of the heat previously stored up in the walls of the chambers in which it is contained, and there passes off from those chambers a mixture of gases and vapours containing both free chlorine and vapour of hydrochloric acid. This mixture of gases and vapours passes off from A, A, A, A, by the horizontal channels a, a, a, a , into the vacant space between the masonry of the furnace and the door F, and then passes by the channel l , Fig. 7, into the pipe m , Figs. 7 and 8. From the pipe m the mixture of gases and vapours is conveyed to apparatus for condensing out of it vapour of hydrochloric acid, and what passes off from that apparatus then goes on to apparatus for the absorption of chlorine. The air which enters the chambers A, A, A, A, through apertures in the door E, is drawn in by means of an aspirator. When the decomposition of the oxychloride has proceeded sufficiently far, the admission of air into the working chambers is arrested, the door F is opened, and the residual oxide contained in the chambers A, A, A, A, is discharged. That residual oxide is drawn out of the horizontal channels a, a, a, a , by means of a suitable rake. When the residual oxide has been completely discharged the cover of the opening H is replaced, and then the door E having been opened, the movable regenerative burner is brought back into the position in which it is shown in Fig. 6, and the decomposing chambers of the furnace proper are then heated up again for another operation. Table B gives the results of several operations of decomposition. Fig. 11 shows the result of a special operation made at my request with a view to determining the rate of evolution of the chlorine.

FIG. 11.—PROGRESS OF DECOMPOSITION OF OXYCHLORIDE OF MAGNESIUM



Of course in actual working care would be taken to make the operations in the various decomposing furnaces overlap one another, so as to maintain the percentage of chlorine at a fairly constant average. The form of the curve obtained in this experimental operation suggested to my mind that the reaction was a reversible one; that is to say that when, as in this case, magnesium chloride is treated by oxygen, it forms magnesium oxide and chlorine, and when the resulting magnesia is treated by chlorine it gives chloride of magnesium and oxygen. In order to arrive at an accurate understanding of the matter I determined to make a series of experiments myself.

First, however, I looked up the literature of the subject in the best textbooks, but could find no mention of it. But when I went back to Davy I found that he did know that magnesia treated by chlorine gives chloride of magnesia + oxygen, and I found further that Graham knew that chloride of magnesia + oxygen yields magnesia + chlorine. However, all these facts appear to have been eliminated from our modern manuals. We will now make an experiment to prove this interesting reaction. My assistant has here a porcelain tube containing anhydrous oxychloride of magnesium. If he slowly passes through this tube a current of oxygen we shall collect at the other end an equivalent quantity of chlorine. If he now reverses the operation, substituting a current of chlorine, we shall obtain as the product a continuous current of oxygen. Therefore the reaction is a balanced or reversible one. Calling one end of my apparatus A and the other end B, I found that by passing oxygen from A to B, I obtained from 82 to 77 per cent. of chlorine, and by reversing the current and passing it from B to A I got 75 to 78 per cent. in the resulting gas. Whichever way I worked the result was practically the same, 75 per cent. of chlorine and 25 per cent. of oxygen. Then, by passing chlorine from A to B, I obtained 22 to 28 per cent. of oxygen, and from B to A 26 to 24 of oxygen in the gaseous mixture. The impression I had formed from the curve given in the above diagram was therefore amply confirmed. My theory of the decomposition which goes on in the furnace is that, in the first stage, there is a rapid evolution of steam; the steam decomposes a portion of the magnesium chloride, producing hydrochloric acid, which passes off with the vapour of water. What remains is anhydrous magnesium chloride and magnesia, and this mixture then undergoes the reaction which we have just seen by the action upon it of atmospheric oxygen. I shall pursue these experiments further, because it will be interesting to know whether the decomposition will vary with a varying pressure of oxygen. Finding in my first experiment that three-fourths by volume of the original oxygen was replaced by chlorine I inferred that three-fourths of the oxygen contained in the air would be the proportion which would replace the chlorine at the temperature attained—viz., a full red heat, or nearly 1000° C. I therefore looked for 15 to 18 per cent. of chlorine when I used air; instead of which I got 30 per cent., showing a nearly complete absorption of the oxygen.

The products of the decomposition have to be drawn off from the furnace by means of a diminished pressure steadily maintained. For this purpose M. Pechiney employs an aspirator consisting of two small gasometers of cylindrical form, plunging in a concentrated solution of chloride of calcium. This solution is used rather than pure water, because Cl is nearly insoluble in it. These cylinders have a regular

vertical movement, alternately up and down. A tube traverses the bottom of the vat which contains the solution of CaCl_2 , and rises in the interior of the cylinder to a height superior to that which the liquid attains. When the cylinder rises it causes aspiration by means of this tube, and when it descends it drives back, through a tube, the gases with which it was previously filled. The said tube is connected outside the cylinder with two other tubes, one of which is fixed to the apparatus through which pass the aspirated gases, the other being fixed to the apparatus through which pass the rejected gases. Each of these new tubes is closed alternately by valves worked by the movement of the apparatus itself; that is to say, when the cylinder ascends the valve of the suction tube is opened and that of the ejecting tube is closed, and when the cylinder descends the valve of the ejecting tube is opened and that of the suction tube is closed. The two cylinders of the pump in question are suspended at the extremities of a balance, so that while one is rising the other is falling. The action of aspiration and rejection is therefore nearly continuous and regular. The aspirator is not in immediate connexion with the decomposing furnace, but acts through:

1. An ordinary HCl condensing tower.
2. A number of sandstone bonbonnes.
3. A glass tube refrigerator.

This refrigerator consists of a stone tower, of square or rectangular horizontal section, in the interior of which tower are arranged, in an inclined position, glass tubes, through which cold water is kept flowing. The said stone tower, in the interior of which the said glass tubes are placed, may be constructed after the same manner as the towers in which the vapour of hydrochloric acid which is generated in the first stage of the manufacture of soda by the Leblanc process is usually condensed. This tower is shown in vertical section in Fig. 9 and in horizontal section in Fig. 10. Two opposite sides of the said tower are each pierced with holes. These holes should preferably be arranged in horizontal rows, those of any one row except the lowest being, not immediately above the holes in the row beneath it, but above the spaces between the holes in the row immediately beneath. In Figs. 9 and 10 the two sides of the tower which are so pierced with holes are marked A and B. In Figs. 9 and 10 the glass tubes are marked c, c, c, c. One extremity of each of these glass tubes protrudes through one of the holes in the A side of the tower, and its other extremity protrudes through the corresponding hole in the opposite or B side of the tower. On the A side of the tower (which may of course be whichever of its four sides is most convenient in each case) the protruding extremity of each glass tube is connected by a piece of caoutchouc tubing, or other equivalent appliance,

TABLE B.
DECOMPOSITION OF DRY OXYCHLORIDE OF MAGNESIUM.

Weight of Cl Charged.	Cl in the Residues per 100 of Cl Charged.	Per 100 of Cl Charged.			Per 100 of Total Cl Disengaged.		Weight of Free Cl per Operation.	Maximum Percentage of Cl in the Gases.
		Total Cl Disengaged HCl + Cl.	Free Cl.	HCl.	Free Cl.	HCl.		
Kilos.							Kilos.	
415	17.60	82.40	42.40	40.00	51.40	48.60	176	6.25
408	19.00	81.00	42.90	38.10	52.96	47.04	175	6.45
414	16.00	84.00	44.68	39.32	53.20	46.80	185	7.15
420	15.00	85.00	45.23	39.77	53.20	46.80	190	7.78

marked *d, d, d*, in Figs. 9 and 10, with one of the tubes or pipes some of which are marked *T*. These tubes *T* may be of iron or other convenient material. Water passes into these tubes *T* from the hollow column *N*, and then from the tubes *T* into the glass tubes *c, c, c, c*. On the *B* side of the tower the protruding extremity of each glass tube is connected with a piece of caoutchouc tubing, or other equivalent appliance marked *d'*, by which, in each case, water

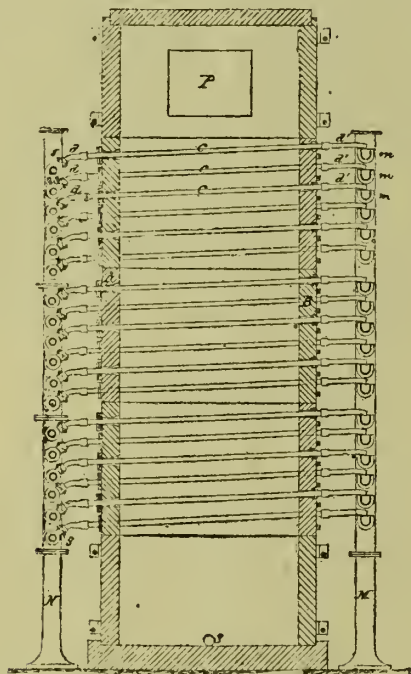


FIG. 9.

which has entered one of the glass tubes from the hollow column *N* by one of the pipes *T*, and has traversed the glass tube, passes from that glass tube and is discharged into one of the gutters or conduits *m, m, m*. From the gutters *m, m, m*, the water discharged from the glass tubes passes away by the hollow column *M*. In order that the glass tubes *c, c, c, c* may not be liable to break, it is necessary that they should be kept always full of water. This result

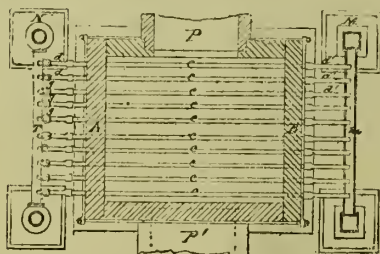


FIG. 10.

may be secured by slightly inclining the glass tubes, as in Fig. 9, placing that extremity of each of them by which water enters it a little lower than that extremity of it by which water is discharged from it. When the mixture of vapours and gases which the apparatus is employed to cool is one from which an acid liquor condenses during the operation of cooling it, this acid liquor will condense upon the glass tubes, and will run along each tube towards its lower extremity, being the extremity of it which is at the *A*

side of the tower, or at the side of the tower at which the cooling water enters the glass tubes. It is, therefore, necessary that, at that side of the tower, the joint between the glass tube and the stone through which it passes should be perfectly tight. It will be seen that upon that extremity of the glass tube *c* which protrudes through the *A* side of the tower there is placed a short piece of caoutchouc tubing upon which is a caoutchouc flange, which flange comes in contact with the face of the stone through which the tube passes, and is pressed tightly against the face of that stone by the tubular flange of the gland *n, n*, that tubular flange of the gland *n, n*, being pressed tightly against the annular flange of the piece of flanged caoutchouc tubing *i, i*, by means of screws passing through the annular flange of the gland *n, n*, and working into the iron bar or band *R, R*. The joint between the other extremity of each glass tube *c* and the stone through which it passes on the *B* side of the tower may be made simply by means of any cement unattackable by acids. The gas or vapour to be cooled by this apparatus should preferably enter near the top of the tower, for example at *P*, Figs. 9 and 10, and the cooled gas or vapour should preferably pass off from near the bottom of the tower, on the opposite side of it, as at *P'*, Fig. 10. Any liquid condensing in the tower will pass out of it by the aperture *S*, Fig. 9. It will be evident that if one of the glass tubes, *c, c, c*, happens to break, the broken tube can be removed and a new one put in its place very readily, and without stopping the working of the apparatus. The fact that a tube has broken will be perceived by an increase in the quantity of liquid discharged from *S*, and which tube it is which has broken will be indicated by water ceasing to issue from that extremity of the broken tube which protrudes through the *B* side of the tower. The cock *g* of that tube may then at once be closed, and the broken tube be removed, and a new one substituted for it, without interrupting the working of the apparatus.

It is this last apparatus which is in immediate connection with the decomposing furnace by means of a pipe. The gases leaving the decomposing furnace by the pipe *M* pass, by another pipe, into the glass tube refrigerator. There they are condensed. From the refrigerator they pass on through a series of sandstone bonbonnes and, lastly, through a condensing tower. In their passage above described the gases have been deprived of the whole of their *HCl*, and they now enter the cylinders of the aspirator as a mixture of air and chlorine gas. It is this gaseous mixture which the cylinders drive into special apparatus wherein they are brought into contact with milk of lime, which is gradually transformed into a mixture of chlorate of lime and chloride of calcium. It is by the volumetric measurement and the analysis of this liquid that the production of chlorine is calculated.

The hydrochloric acid condensed in the refrigerator, in the bonbonnes, and in the tower, is all mixed in a single reservoir, and yields an acid averaging about 12° B. It would be possible to obtain a much stronger acid, thus:—The vapour which at the beginning of the operation is condensed in the glass tube refrigerator contains an enormous proportion of water, and only a small proportion of *HCl*. But later on the proportion of water diminishes greatly, while the proportion of *HCl* does not diminish. It would be possible to condense the relatively strong gaseous *HCl* in the weak aqueous acid of the refrigerator and the condensing tower. This has not yet been done, but it is a course which would suffice to bring the whole of the aqueous *HCl* of the process to a strong degree. For proof of this it will be sufficient to compare, in the figures which will be

given later on, the relative quantities of HCl gas and vapour of water which are disengaged during the decomposition.

The decomposition of oxychloride of magnesium produces, as we have just seen, free chlorine and aqueous hydrochloric acid. The proportion of the Cl given off in the free state to that disengaged as HCl is as 53 to 47. There remains in the residues a quantity of Cl equal to about 15 per cent. of the total Cl charged into the furnace.

Consequently there is obtained per 100 of chlorine charged :—

Cl remaining in the residues	15.00
Free Cl	45.23
Cl as HCl	39.77
	100.00

Or, as these 100 of chlorine charged arise from 107 of Cl commenced with [there being a loss of 6.60 per cent. during the operation of drying], 100 of original chlorine would be accounted for thus :—

Cl lost in drying	6.60
Cl remaining in the residues	14.00
Free Cl	42.25
Cl as HCl	37.15
	100.00

If, besides this, we admit a loss of 5 per cent. of Cl during the various manipulations, especially in emptying the tanks in which the magnesium chloride is clarified, a loss which, if taken at 5 per cent., is certainly exaggerated, the account of each 100 of Cl put in work would be

Cl lost { In the various manipulations 5.00 } absolutely { In drying	6.27 } 11.27
Cl entering { Remaining in the residues.. 13.30 } again into { Condensed in the state of HCl 35.29 }	48.59
the process	
Cl produced in the free state	40.14
	100.00

Consequently, to produce 40.14 of free Cl one must consume 100—48.59 or 51.41 of Cl. The result in free Cl of the Cl entering the process is therefore 78 per cent.

One can see at a glance that this result can be improved only by succeeding in one or more of three things :—

1. In diminishing the loss of Cl.
2. In increasing the proportion of free Cl yielded.
3. In diminishing the quantity of Cl remaining in the residual magnesia.

It is probable that the process will improve in all these various ways. And to produce this effect one means will suffice—viz., the improvement of the heating of the decomposing furnace. At present we obtain therein a mean temperature of about 1000 degrees C. It is necessary to greatly increase that temperature.

The magnesia when it is taken out of the furnace is, firstly, cooled by putting it in a vessel provided with a mechanical agitator, this vessel itself being placed in another vessel, and cold water being circulated through the space between the two. The MgO having a very weak capacity for heat is quickly cooled. The mechanical cooling is necessary, however, because MgO is an extremely bad conductor of heat. When the magnesia is cooled sufficiently it passes into a rotary sieve, which separates it into two parts :—

1. The more important part (about $\frac{2}{3}$), which passes through the sieve as a fine powder, being almost entirely decomposed, containing hardly 4 per cent. by weight of Cl.

2. The less important part (about $\frac{1}{3}$) which cannot pass through the sieve. This latter is oxychloride hardly at

all decomposed, retaining no water, it is true, but containing much Cl, sometimes as much as 40 per cent. by weight. *This portion of the residue is at once mixed and re-charged with oxychloride from the fourth operation.*

It will be seen, therefore, that when native chloride of magnesium is treated, the magnesia which will be drawn out will be the *fine* magnesia, containing not more than 4 per cent. by weight of Cl—a small proportion considering the low equivalent of magnesia.

At Stassfurt, the working of 100 parts of $MgCl_2 \cdot 6H_2O$ (containing, say, 35 parts of Cl) will yield a residue of about 20 parts of MgO. At the rate of 4 per cent. these 20 parts of MgO will contain 0.8 part of Cl, or only 2.3 per cent. of the total chlorine entering the process. Such a loss of Cl will be insignificant.

The present installation at Salindres comprises two furnaces of nine chambers each. These chambers are each 3 metres high, 1 metre long, and 0.08 metre wide. These two furnaces, heated alternately by a single regenerative burner, constitute a unit. It has been seen that such a unit should produce per 24 hours 1000kilos. of free Cl with three operations to each furnace, say six operations in all, or about 170kilos. per operation. Instead of which, at present, owing to the insufficiency of the heating apparatus, we can make only two operations in each furnace, or four operations in all per 24 hours, which give, according to the heat of the furnaces, from 180kilos. to 190kilos. of free Cl each. There is obtained, therefore, per 24 hours, from 720 to 760kilos. of free Cl. The improvement of the heating of the furnaces would considerably change all the results. Indeed, if the furnaces could be made considerably hotter, one might dry the oxychloride a little less than at present without fear that the increased humidity of the material charged would inconveniently lower the temperature of the furnace. And as it is the expulsion of the last portions of the water driven off which causes the principal loss of HCl in the fourth operation, it will thus be seen that that loss might be considerably reduced. Moreover, with hotter furnaces, the quantity of total chlorine disengaged (Cl + HCl) would be greater, or in other words the decomposition would be more complete. And, lastly, with hotter furnaces, the decomposition would be more rapid, so that at least five operations might be made per 24 hours instead of four, as at present, and that without proportionately increasing labour or the consumption of coal. In a word, if a higher temperature is obtained in the furnaces, the quantity of chlorine will be greater, and the cost per ton for producing it will be less.

It has been said above that the respective quantities of steam and gaseous HCl which come from the decomposing furnace are such as not to prevent the obtainment of a concentrated aqueous HCl. In fact, for every 100 of chlorine charged there is obtained a quantity of Cl in the state of HCl—to 39.77. And it is shown above that in the dried oxychloride 33.3 of Cl are accompanied by 21.62 of water. That is to say, 100 of Cl charged are accompanied by

64.8 of water	64.8
But the above 39.77 of Cl have been disengaged in the state of HCl holding a quantity of water—	100
The quantity of water disengaged is thus only	51.8

and this quantity is not sufficient to condense the 39.77 of Cl in the state of HCl—which in reality represents about 41 of HCl.

Having now described the process itself, let us consider the question of cost of production, and in that respect compare it with the old Weldon process. The latter was essentially a cheap method. The

plant required for it was not an expensive one, nor did it involve any great cost for repairs. The plant for the new process is more complicated, and consequently more expensive. On the other hand, the results obtained have increased the confidence which M. Pechiney has always had in the process, and have decided him to commence at once the erection of an industrial installation to work on a scale of 6000kilos. of free chlorine per day. Speaking of the small experimental plant which he has been working since last July, M. Pechiney says:—

1. We produce at the present time from 720 to 760kilos. of chlorine per 24 hours, at the following cost:—

Coal for the drying and decomposing furnaces..	3300kilos.	
Coal for mechanical work	500 "	
Coal for concentrating		
MgCl ₂	500 "	
	1300kilos. @ 12fr.	Francs.
Labour		51'60
Repairs		74'00
Loss of magnesia (?)		20'00
		5'00
		150'60

Say for 1000kilos. at the most 209'20fr.

2. If in working the one unit we succeed in producing 1000kilos. of Cl per day instead of 740kilos. as at present, by getting a higher temperature and a more rapid decomposition in the furnaces, the only expenses which would be increased (but which would certainly not be increased proportionately) would be those for fuel and magnesia. The other expenses would remain unaltered. The expenses for a production of 1000kilos. of Cl would then at the utmost amount to:—

Coal, 6000kilos. @ 12fr.	Francs.
Labour	72'00
Repairs	74'00
Loss of magnesia (?)	20'00
	7'00

Say for 1000kilos. of chlorine 173'00

3. The experience which we now have of the process, and certain improvements which we see our way to make in the heating of the decomposing furnace and in various points of detail, warrant us in expecting, with an installation producing 6000kilos. per 24 hours, the following cost of production per 1000kilos. of Cl:—

Coal, 4000kilos. @ 12'00fr.	Francs.
Labour	48'00
Repairs	15'00
Loss of magnesia	20'00
	5'00

Say for 1000kilos. of chlorine 118'00

It will be seen at once from these figures and from some which will follow, that the main expense of the process is for fuel, and that if fuel were as cheap in France as in England, M. Pechiney would be able to produce a ton of chlorine at the same working cost as he calculates it is now produced in England by the old Weldon process—viz., 94 francs. There is no doubt that the main feature of the new process is economy of hydrochloric acid; for whereas the old Weldon process yields only 33 per cent. of the Cl entering into it, the process now under consideration yields 78 to 80 per cent. at least. Roughly speaking, therefore, the economy effected by it as compared with the old process, may be said to be the equivalent value of two tons of absolute HCl per ton of Cl produced. Now, Mr. Weldon has himself estimated the value of HCl. He says (this Society's Journal, 1883, p. 434):—"HCl costs the Leblanc soda maker 36 per cent. of the total cost of the process by which he obtains it. The cost of that quantity of HCl, which is required by the present Weldon process for the manufacture of one ton of B.P., amounts to more

than all the other items of the cost of that ton of B.P. put together. I believe M. Pechiney will eventually succeed in realising a cheap process which will diminish the present cost of B.P. for HCl by not less than two-thirds." He estimated the value of 27 per cent. acid to the Leblanc soda maker to be about £1 per ton, and he arrived at that value by taking the difference in the cost of producing a ton of soda by the Leblanc process and the ammonia process. That difference, he maintained, was the value to the Leblanc manufacturer of the quantity of acid which he produced in the making one ton of soda. It is incorrect to say that the value of HCl has diminished, though it is possible that the selling price of HCl has materially diminished. This decrease can be explained by the fact that the manufacture of B.P. having diminished by reason of an arrangement between the makers, there is a little more HCl for disposal. But this decrease in the selling price applies only to a certain limited quantity of HCl. The real value of HCl ought not to be expressed by the selling price of certain quantities of acid, but rather, as Mr. Weldon always maintained, by the difference between the cost price of ammonia soda and the cost price of Leblanc soda. Now, one ton of soda ash of 58 per cent. corresponds to about 2 tons 6cwt. of aqueous HCl of 28 per cent. If this latter is worth only 10s. per ton, there ought to be a difference of only 26s. per ton of 58 per cent. ash between Leblanc and ammonia soda. The difference is much greater than 26s., and must be nearly double that, say 50s. By finding the difference in the cost price of the two soda processes, I fix the value of HCl, and that difference is such as to bring the value of aqueous HCl of 28 per cent. to very nearly £1 per ton. Admitting, however, its value to be only 16s. per ton, that would bring the value of a ton of gaseous HCl to £2 16s.

It is possible, of course, that circumstances may be changed in the future—for example, by the recovery of sulphur; but that will be of no great importance. At present, the pyrites sulphur entering the Leblanc process at 3d. per unit, costs nearly 10s. per ton of 58 per cent. soda ash. If Mr. Chance succeeds in recovering sulphur at an average cost of 1d. per unit, the expense for pyrites will be lessened by two-thirds, or 6s. 8d. per ton of 58 per cent. soda ash. This would reduce the value of the 2 ton, 6cwt. of 28 per cent. HCl by 6s. 8d. in all, or say 2s. 6d. per ton.

It is therefore incorrect to say that the value of HCl has diminished in England during several years past. The value of HCl should increase in proportion as the selling price of alkali decreases. And for several years past the selling price of alkali has not ceased to decrease. The selling price of English soda ash and caustic soda is now 20 to 25 per cent. lower than it was in 1884. I admit, however, that this reduction is to some extent due to improvements in Leblanc plant, large furnaces, etc.

We have said above that for the English Leblanc manufacturer HCl gas ought to have a value of £2 16s. per ton. On the other hand the *probable* cost price of Cl per 1000kilos. at Salindres will be—

Coal, 4000kilos. @ 12fr.	Francs.
Labour	48'00
Repairs, etc.	45'00
Loss of magnesia (?)	20'00
	5'00
	118'00

The cost price will not be the same in England, for the simple reason that coal costs there only 6fr. per ton instead of 12fr. as at Salindres. The cost price in England would therefore be—

Coal, 4000kilos, @ 6fr.	Francs.
Labour	21'00
Repairs, etc.	45'00
Loss of magnesia (?)	20'00
	5'00
	91'00

That is to say, in England one ton of Cl will cost the same amount as by the old Weldon process.

To this conclusion two objections may be made:—

1. The cost price of 118fr. at Salindres mentioned above, is a *calculated cost not yet realised*. The experience gained of the new process warrants M. Pechiney in expecting that he will realise this result when an experimental plant producing only $\frac{3}{4}$ ton per day shall be replaced by an installation working on a scale of 6 tons per day, and to the working of which an experience which increases constantly will be applied. It is with the expectation that the above estimate will be the maximum rather than the minimum that this probable cost price of 118fr. is given.

2. Wages, it may be said, are much lower in France than in England. Consequently, if 45fr. is the cost for labour in France a much higher sum will be required for England. An English workman, however, does more in a day than a French workman. So that, notwithstanding the lower wages in France, the expense for labour *per ton of material produced* is nearly the same in both countries.

The cost in England of 1 ton of chlorine obtained from the old Weldon process as compared with the Weldon-Pechiney will thus be as follows:—

1.—THE OLD WELDON PROCESS.

Cost price of 1 ton of chlorine 91fr. = ...	£ s. d.
Value of $3\frac{1}{2}$ tons of HCl gas at 56s. = ...	3 15 0
	9 6 0
	13 1 0

2.—WELDON-PECHINEY PROCESS.

Cost price of 1 ton Cl 94fr. = ...	£ s. d.
Value of $1\frac{1}{2}$ tons HCl gas at 56s. = ...	3 15 0
	3 14 0
	7 9 0

Therefore the saving by the latter process = £13 1s. less £7 9s., or £5 12s. per ton of Cl produced.

But, alas! where will the English manufacturer sell his bleaching powder if he produces $3\frac{1}{2}$ tons instead of $1\frac{1}{2}$ tons, as now?

But there are other matters to be regarded in considering the applicability of this process. In 1884 Mr. Weldon expected that its first effect would be to replace the Leblanc process by the ammonia process; because he then thought it probable that his new chlorine process might be used in conjunction with a method for decomposing the residual NH_4Cl of the ammonia soda process by MgO . And, although it is not my intention to go into that part of the question now, there is no doubt that that end could be attained if ammonia soda makers were willing to add to their already costly plant the additional expensive plant which would be necessary. M. Pechiney has patented a process and apparatus for thus treating NH_4Cl ; and, moreover, Mr. Chance has proved that it is easy to transform calcium chloride into magnesium chloride by treating it with carbonic acid in presence of magnesia.

And this leads us to the more serious question, as to whether English manufacturers will care to use this new chlorine process in conjunction with the Leblanc soda process. In considering this question, we have to face the difficulty that magnesium chloride exists as a raw product at a place not far removed from a port easily available for the distribution of material, and from which centre enormous quantities of chemical products are already sent out—namely, Stassfurt. In the very able paper on the “Stassfurt Salts Industry,” which Mr. Hake read before this Section in 1883 (p. 150),

he said, speaking of the residual solution of magnesium chloride: “Many proposals have been made and numerous patents taken out for the further utilisation of this mother-liquor, but it still figures largely as a waste product. Of the 6,000,000 cubic feet yearly produced, corresponding to 150,000 tons of dry MgCl_2 , one-half only is recovered, the remainder being run into the river, carrying with it 300,000lb. of bromine.” Chloride of magnesium therefore costs at Stassfurt practically nothing. It is run into the rivers in the form of a solution almost as concentrated as that which is made at Salindres by dissolving the MgO of the process in HCl . The solution, therefore, has to undergo no more evaporation than is now made at Salindres, the cost of which is included in the estimated cost price of 118fr. per ton of Cl. However, as the Stassfurt solution contains some foreign salts (especially SO_3MgO and NaCl), which are deposited during the concentration, one may admit that the operation costs a little more than the evaporation made at Salindres, say 250fr. more per ton of $\text{MgCl}_2 \cdot 6\text{H}_2\text{O}$ —or for $3\frac{1}{2}$ tons, corresponding to $1\frac{1}{2}$ tons HCl , 937fr., say 10fr. more.

The cost of 1 ton Cl at Salindres being	Francs.
Will be increased, as we have shown, by	118'00
	10'00
And will thus become	128'00
But it is still necessary to deduct for the loss of magnesia (which will be nil at Stassfurt, where $\text{MgCl}_2 \cdot 6\text{H}_2\text{O}$ has no value), say	5'00
The cost of Cl per ton at Stassfurt will thus be..	123'00
Or say £5.	

To arrive at this result, it is assumed that fuel and labour cost the same at Stassfurt as at Salindres. In which case, chlorine and chlorine products will be produced at a much cheaper rate at Stassfurt than in England. On the other hand, Stassfurt is not so well situated as the English works for the exportation of B. P. However, the difference in this respect will not be great. The carriage from Stassfurt to Hamburg is about 6s. per ton by water and 9s. by rail. And the situation of Hamburg is as good on the whole for exportation as that of the English alkali works.

It would seem clear, therefore, that the natural place for the adoption of this process is Stassfurt. And if it can be worked there as economically as I expect it will—producing chlorine at less than one-half its present cost, it will become a serious question whether, even with the advantages which Mr. Chance is securing for it, the Leblanc process will be able to stand against its rival. If this process succeeds at Stassfurt, the natural result in England will be a decrease of the amount of soda made by the Leblanc process, and an increase of the happiness of the ammonia soda makers. Mr. Mond and Mr. Solvay may, and probably will in time, succeed in developing their respective processes for producing chlorine from NH_4Cl and CaCl_2 ; but it will take a great deal to beat this process if it is applicable to the refuse chloride of magnesium of Stassfurt.

I will only say, in conclusion, that I think Messieurs Pechiney and Boulouvard deserve the very highest commendation for the labour, zeal and ingenuity which they have expended on the development of this process. There can be no doubt that the enormous personal enthusiasm which Mr. Weldon had, and the marvellous power he possessed of communicating a share of that enthusiasm to others, has been the mainspring which has induced these gentlemen, as a matter of honour to his memory, to endeavour to finish this work, believing all the time that it would ultimately attain that success which he had anticipated. I cannot conclude without quoting a few words of the inventor of this process, uttered from the spot on which I now stand. In his note on the influence of the ammonia soda process on the value

of hydrochloric acid (see this Journ. 1883, 435) Mr. Weldon said: "If this process succeeds, and I am still among you, I will ask permission to give an account of it before this Section; and I can imagine few things more delightful than to be able then to tell you that the old Weldon process, after having forced its way into every chlorine work in the world except two, and those unimportant works, peculiarly situated, has at last passed into the limbo of things which have served their time."

NOTE.—I have to acknowledge the very great assistance I have derived from Mr. Renaut, Secretary of the Weldon's Chlorine Processes Company, in the preparation of this paper.

DISCUSSION.

The CHAIRMAN said the paper was one of singular interest from every point of view. Though it raised painful memories of the loss they had sustained by Mr. Weldon's death, everyone must feel a deep satisfaction in the fact that his labours had not been lost, and that his French fellow-workers had been able to carry out his plans with such marvellous skill and perseverance. The President had given a most beautiful exemplification of the fact that the highest science may find its application in technical chemistry, by working out before the meeting the real character of the reaction which took place in the process described. This was a process which proved the importance of engineering skill in its relation to manufacturing chemistry. He was not one of those who shared the delusion that the future of English manufacturers would be greatly helped by technical education given to boys of fourteen. Something was wanted which no boy of fourteen ever had—viz., the highest skill in pure chemistry coupled with a sound knowledge of physics, and to both must be added engineering capacity of the highest order, if any real progress was to be made in manufacturing chemistry. Without such knowledge even skilled chemists were apt to fall into the error of supposing that because an experiment went well in the laboratory it would go equally well when tons were dealt with—forgetting the enormous cost of manipulating large masses of material.

Sir HENRY ROSCOE heartily endorsed the remarks of the Chairman as to the importance of engineering skill to applied chemistry. At first sight he had been almost frightened by the complicated character of the apparatus shown—many parts of which, especially the glass-tube cooler, were striking examples of engineering skill and attention to detail. He would like to know whether bleaching-powder could be made from gases containing at the maximum only about 8 per cent. of chlorine, or whether M. Pechiney had confined himself to the manufacture of chlorate only. No doubt the late Mr. Deacon had made bleach from a very dilute chlorine, but he could not remember whether its strength was ever so low as 8 per cent. The question of technical education was not to be settled by merely teaching boys. Masters needed teaching as well; and the highest scientific instruction was needed in order to bring England up to the mark—or rather to keep her there. This process had been worked out by the skill of two eminent French engineers, but Mr. Weldon's own work was a brilliant example of what Englishmen could do. With such workers, and with higher education, England would not fail to keep her position.

Sir FREDERICK ABEL was glad to have an opportunity of expressing the pleasure he had felt, not only in listening to an interesting account of the last work of his friend Weldon carried on to completion by M. Pechiney, but in seeing Professor Dewar

throw himself, as they knew he could, with the greatest ease, from the highest branches of physical chemistry into the elucidation of practical processes, to the advantage of those who followed them, and thus illustrating the importance of a thorough education in all branches of science.

Mr. ALEXANDER M. CHANCE thought that the Chairman had called upon him for an opinion three months too soon. He might have something to say about it when he read his paper in March.

Mr. E. K. MUSPRATT was glad to find in the President's opening remarks a confirmation of the opinion he had expressed in addressing the Society from the same position—viz., that progress in industrial chemistry had now taken the form of the development of chemical engineering. The ammonia-soda process, as patented by Dyar and Hemming, in 1837, was perfect chemically, but his father and Mr. Young had failed to work it economically simply because their apparatus was imperfect; and M. Solvay's merit lay in the fact that he had overcome the engineering difficulties. However interesting the process under consideration might be from a chemical point of view, if it was to become a manufacturing process it could only be by reason of the perfection of the apparatus employed. And it would be seen by the diagrams exhibited that it was not a question of one piece of apparatus, but of a whole series. In going through the works of Messrs. Pechiney & Co. he had been deeply impressed by the admirable manner in which every engineering detail had been carried out. M. Pechiney's glass-tube cooler was most ingenious. Mr. Deacon had tried to cool the hot gases coming from his decomposer by a glass-tube apparatus in which the tubes were arranged vertically, instead of horizontally, as in M. Pechiney's apparatus; but his tubes broke so rapidly that he had to abandon the idea. M. Pechiney got his tubes from Belgium, and they were probably better than the English tubes. With respect to the question of the cost of the process and the probability of its going to Stassfurt, he did not think anyone could yet speak positively. It was true that at Stassfurt the raw material was in one sense much cheaper than either in England or France; but then the working loss of magnesia was put at only 5fr. out of 118fr., or, say, 5 per cent. England, on the other hand, had a great advantage in cheaper fuel; for it would be seen that simply on account of the higher price of fuel, the ton of Cl cost 25 per cent. more at Salindres than it would in England. He was not familiar with Stassfurt, but he understood that the fuel in use there was an inferior quality of lignite, and there would be difficulties in obtaining the high temperature required, which would make the fuel dearer. He did not fear, therefore, being absolutely bowled over by the Stassfurt manufacturers. He thought it probable that there would be some, though not insurmountable, difficulty in making bleach from a dilute chlorine such as this process yielded. The average strength of Deacon chlorine was 9 or 10 per cent., and he knew that with that percentage it was difficult to absorb the chlorine in hot weather. For the manufacture of bleaching liquor and chlorates, however, such a dilute chlorine would be quite applicable—it being merely a question of size of apparatus. M. Pechiney at present used the chlorine obtained by the new process for the manufacture of chlorate of potash. If he could produce his chlorine in that form cheaper than could the English manufacturer, the latter would be affected just as much as if bleaching-powder were produced, since the two manufactures were, so to speak, convertible. The effect would be that the English manufacturer would be able to make bleaching-

powder only. He did not take a despondent view of the future of the English chemical trade. Though England might have fallen behind in some matters, she had advanced in others. English workmen were still, taking them all round, equal to, if not better than, Continental workmen. What was wanted was a more thorough education of the higher middle-class, and that would, he believed, be supplied by such institutions as the Owens College, and the new colleges at Liverpool and Leeds.

Dr. D. B. HEWITT was not prepared to criticise the process. Such an invention, however, was a matter of the greatest interest to everyone concerned in the manufacture of soda or chlorine products. Many active minds were at present engaged on similar problems, and he expected great advances to be made during the next five years. The result of increased knowledge might appear to be at one time to pinch the ammonia manufacturer, or at another time the Leblanc manufacturer; but, in the end, no one would find himself much the worse, and the human race would be benefited. An increased population and growing civilisation would create an increased demand for these articles in proportion to the development of the processes producing them. It was extremely remarkable that notwithstanding the vast development of the ammonia soda process, the decomposition of salt in England by the Leblanc process had been affected very slightly; and the Leblanc soda manufacture still showed a remarkable vitality. With respect to the utilisation of dilute chlorine, long experience enabled him to express a firm conviction that there was no difficulty whatever in making bleaching powder with chlorine that varied from 4 to 8 per cent. by volume. In a Deacon chamber there was no difficulty in absorbing the Cl to the very last traces. That he had proved to the satisfaction of Dr. Angus Smith. The whole difficulty consisted in obtaining the gases free from any bodies which would spoil the bleach. If the gases contained neither carbonic acid, hydrochloric acid, nor water, good bleach could be made even if only 3 per cent. by volume of chlorine were present in the mixture of gases. Of course as the percentage of chlorine decreased it became more difficult to exclude these deleterious bodies. With respect to the apparatus employed in this process, and especially the glass-tube cooler, words failed him wherewith to express his admiration. The glass-tube cooler seemed to him to have great advantages over the ordinary coke tower for very hot vapour of water mixed with chlorine and hydrochloric acid. As to whether more chlorine would be made at Stassfurt or in England no one could at present speak positively; but there could be no doubt that a great reward was in store for whoever should solve the problem upon which so many scientific men were now at work.

Colonel GAMBLE had not seen the process in operation. He had seen the plant in course of construction nine months ago, and, like everyone who had seen it since, was struck with the amount of engineering skill expended on it. M. Pechiney's belief then was that this process would be the chlorine process of the future—whether of two years hence or twenty years hence M. Pechiney thought might be questionable, but the speaker feared that most chlorine manufacturers now regarded that future as much nearer than they had hoped. The position was a most serious one for the Leblanc manufacturers of this country. They were already blessed with too much chlorine, in the shape of muriatic acid, and had to restrict its use as much as possible in order to make any profits. If the amount of available chlorine from each ton of salt was to be more than doubled, he did not know what would become of them. He

feared Mr. Muspratt had hardly expressed the effect of the possible Stassfurt manufacture as fully as he might have done. He had said that the 5 per cent. loss of magnesia would be balanced in England by cheaper fuel, etc. But the fact was, as Mr. Muspratt was aware, that at Stassfurt they would have not only magnesia but chlorine also for the cost of evaporation. That being so, he feared that bleaching powder would soon be very cheap at Stassfurt, if the process could be satisfactorily carried out with their waste magnesium chloride.

Mr. JOHN PATTINSON quite concurred in the views expressed by previous speakers, that there appeared to be considerable danger of the transference of the chlorine industry from England to Stassfurt; and that real progress in industrial chemistry was now more dependent on the application of engineering ability than on the invention of new chemical processes.

Mr. A. E. FLETCHER thought that, beautiful and ingenious as the apparatus appeared to be from the diagrams shown, manufacturers would look with dismay at the number of parts, knowing as they did that each part would add to the cost of production and maintenance. If, however, this elaborate apparatus produced results not to be obtained otherwise, then all thanks were due to the engineers who had designed it. The condenser had a special interest for him, and appeared to be extremely ingenious and effective. It should not, however, be compared with a coke tower. The latter was well suited to the conditions of the chlorine manufacture as now carried on, the supply of acid being intermittent, and it being therefore necessary to hold a large store of water in reserve, and available for use at any moment. M. Pechiney's condenser, on the contrary, was intended to deal with a constant supply of acid. It had been said that good bleach could be made from very dilute chlorine if it were pure. But of course dilute chlorine was not pure; and although elaborate arrangements might be devised for excluding noxious elements, there would always be the danger of leakage, and thus of the presence of carbonic acid or vapour.

Mr. THOMAS ROYLE inquired on what scale the drawings were supposed to be.

Dr. ALDER WRIGHT asked whether it would not be possible to recover economically some of the HCl lost in drying; secondly, whether the percentage of Cl would not be increased by decreasing the air supply during the process of decomposition, and thus diminishing the total volume of the gases; and, thirdly, whether, supposing the process to be worked at Stassfurt, the by-product of magnesia which would result would not be available for use for making fire-bricks, thus cheapening the production, and perhaps turning the scale in favour of Stassfurt in a way not anticipated.

Mr. C. T. KINGZETT remarked that some 16 years ago he had been associated with the late Mr. Weldon in experimenting a process for the production of chlorine by means of magnesia. In that case no attempt was made to utilise the chlorine directly for the manufacture of bleaching-powder. It was converted immediately into bleaching-liquor. Referring to this more modern form of the process, it appeared that the oxychloride as finally treated contained a large percentage of water. The question therefore arose as to how far the chemical reactions had been determined. Was it supposed that the chlorine resulted only from the action of oxygen on the oxychloride, or did it result in part from the action on the vapour of HCl generated in association? If it resulted from the direct action of air, then Leblanc soda makers would surely have an easy method of

utilising their spare HCl by means of a little magnesia. The process might possibly be improved by moulding the magnesia into blocks suitably arranged so as to be alternately converted into oxychloride by HCl and then decomposing by heat, with the result of the production of chlorine.

Mr. J. W. SWAN thought it would be useful if Professor Dewar could state the relative cost of the apparatus for this process and the old Weldon process; and also to what extent the HCl was actually condensed.

Professor DEWAR in reply said: With regard to the question put by Sir Henry Roscoe, that was the point which first struck me and led to my investigation of the nature of the reaction in the furnace. Of course the practical reply to that question is that no user of the process on a large scale would ever allow his yield of chlorine to go below 5 per cent. As to the assumed difficulty of making bleaching powder from such chlorine, I think the testimony we have had to-night from so high an authority on the subject as Dr. Hewitt, confirming as it does what he said before the Newcastle Section in April, 1885 (this Journal, vol. iv. 311), quite settles the question. If Dr. Hewitt could make 36 per cent. bleach from gases containing only 5 per cent. of chlorine *by weight*, there would surely be no difficulty in dealing with these gases in which the chlorine averages 5 per cent. *by volume*. Moreover, Mr. Mond has always scouted the idea that any real difficulty attached to this point. But even if any such difficulty exists now it will disappear when we succeed, as we certainly shall, in increasing the temperature of the furnace and thus obtaining a quicker decomposition and a higher percentage of free chlorine. I have already made to M. Pechiney the suggestion which Dr. Wright has made to night—namely, that the supply of air should be graduated. With respect to the suggestions made by Mr. Kingzett, I would remark that the oxychloride does not need to be made into blocks; it is a natural property of the material to be somewhat too "blocky." In practice it has been found necessary to use it in small pieces, so that air may thoroughly permeate the mass. Mr. Swan's question is a most pertinent one. I have already stated that the plant for this process will be more expensive than is the plant for the old Weldon process. In fact, M.

Pechiney estimates that, taking the unit of chlorine production at one ton per day, the cost of plant at Salindres for the old Weldon process would be 60,000fr., and for the new process 120,000fr.—that is to say, exactly double. The diagrams shown to-night are not drawn to scale. They are merely illustrations for the purpose of this paper. I may say, however, that the chambers of the decomposing furnace are three metres high, one metre long, and 0.08 metre wide. The hydrochloric acid at present lost could undoubtedly be recovered if it were worth while to do so; but at Salindres they are in the happy position of having a very extensive area and no alkali inspector, and therefore this loss does not trouble them. With respect to the possibility of Stassfurt becoming a centre of the chlorine industry, I should like to quote a few words of my distinguished predecessor in office. In his able address to this Society in July, 1886, Mr. Muspratt said: "If chloride of magnesium is used to replace salt as the raw material for chlorine, this great chemical industry will, of necessity, have its seat in Stassfurt, and not in Lancashire." I think, therefore, that my views on that point are well supported. I of course admit that the process has its difficulties, but I believe that those difficulties will be overcome. For instance, the attainment of a higher temperature in the decomposing furnace will obviate the present loss of chlorine as hydrochloric acid. The oxychloride before desiccation contains 6 equivalents of water; after desiccation it contains only 3 equivalents. If the drying were stopped earlier scarcely any hydrochloric acid would come off in that operation; but we cannot do that until M. Pechiney has carried out his improvement in heating the furnace. Then with respect to the remaining difficulty of undecomposed oxychloride. That will be no great drawback where the process is worked continuously, because these small portions of oxychloride are easily separated from the residues and are worked again. Supposing the process in work at Stassfurt, there will be an accumulation of cheap magnesia which will have been heated strongly, and will therefore be very dense. This magnesia will contain some 3 or 4 per cent. of chlorine, and will therefore be in a condition to form an excellent cement, setting quickly and with a hard, white surface. As Dr. Wright has suggested, such a cement will probably find useful applications, and may thus constitute a source of profit.